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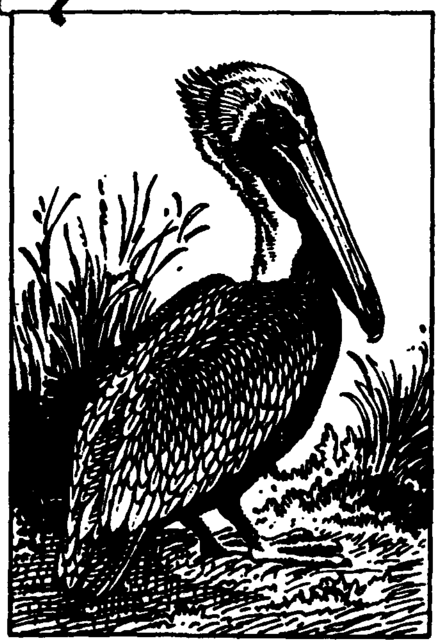
Wetlands Research Program Technical Report WRP-DE-3

A Conceptual Framework for Assessing the Functions of Wetlands

by R. Daniel Smith


August 1993 – Final Report

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	Task		Task
CP	Critical Processes	RE	Restoration & Establishment
DE	Delineation & Evaluation	SM	Stewardship & Management

Wetlands Research Program

Technical Report WRP-DE-3
August 1993

A Conceptual Framework for Assessing the Functions of Wetlands

by R. Daniel Smith
Environmental Laboratory

U.S. Army Corps of Engineers
Waterways Experiment Station
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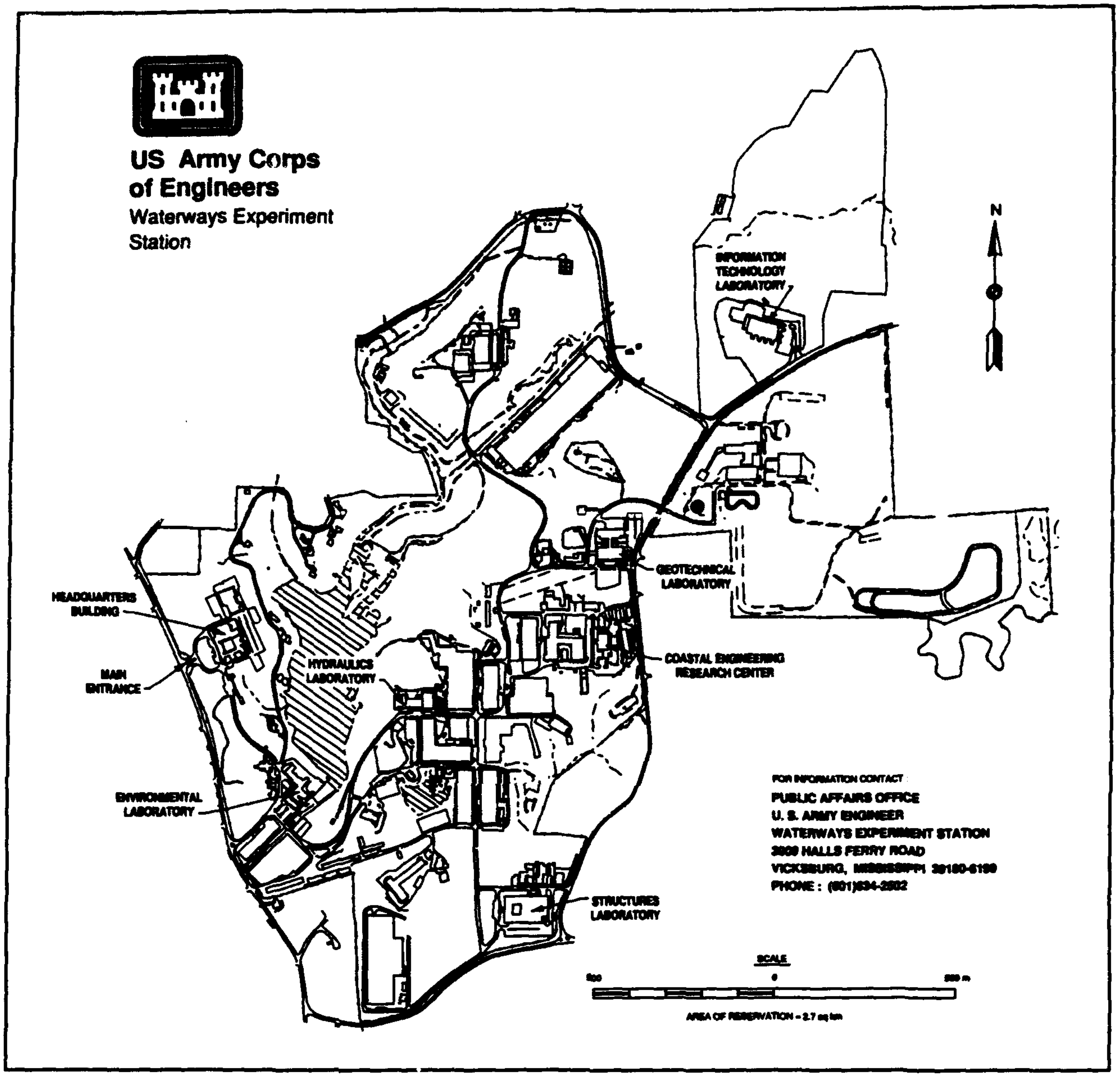

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Wetland Functions

A Conceptual Framework for Assessing the Functions of Wetlands (TR WRP-DE-3)

ISSUE:

The U.S. Army Corps of Engineers is responsible for regulating the discharge of dredged or fill material in "waters of the United States" under its 404 Regulatory Program. As part of the permit review process, the Corps determines the effects of a discharge of dredged or fill material on wetlands and other public interest review factors. Existing methods for determining the effects of a discharge, or "assessing the functions of wetlands," fail to satisfactorily address the administrative and technical requirements of the program.

RESEARCH:

This research identifies the regulatory, administrative, and technical requirements that relate to determining the effects of discharging dredged or fill material in wetlands, avoiding and minimizing effects, and compensating for unavoidable effects. It explores the potential use of different classification and modeling approaches to simplify the assessment process, thereby making it possible to satisfy the administrative and technical requirements of the program. Finally, it proposes an organizational structure for developing assessment methods that use the different classification and modeling approaches.

SUMMARY:

This report outlines a conceptual framework and organizational structure for developing a method to assess the functions of wetlands which satisifies the administrative and technical requirements of the 404 Regulatory Program. While the focus is the 404 Regulatory Program, it is anticipated that the procedure will be useful in the context of other regulatory programs, as well as planning and management activities involving wetland resources.

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Preface

The work described in this report was authorized by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Delineation and Evaluation Task Area of the Wetlands Research Program (WRP). The work was performed under Work Unit 32756, for which Mr. R. Daniel Smith was Principal Investigator. Mr. John Bellinger (CECW-PO) was the WRP Technical Monitor for this work unit.

Mr. Jesse A. Pfeiffer, Jr., of the Directorate of Research and Development was the WRP Coordinator at HQUSACE. Dr. William L. Klesch, Chief, Office of Environmental Policy, HQUSACE, served as the WRP Technical Monitor's Representative. Dr. Russell F. Theriot was the Wetlands Program Manager, and Mr. Ellis J. Clairain, Jr., was the Task Area Manager.

This work was performed at the U.S. Army Engineer Waterways Experiment Station (WES) by Mr. R. Daniel Smith, Wetlands Branch, Environmental Laboratory (EL), under the general supervision of Mr. E. Carl Brown, Chief, Wetlands Branch; Dr. Conrad Kirby, Chief, Ecological Research Division; and Dr. John Harrison, Director, EL.

A number of people and publications were helpful during the development of the report, including the hydrogeomorphic classification of wetlands proposed by M. M. Brinson, a paper by L. C. Lee and K. L. Fetherston discussing issues related to the assessment of wetland functions, and discussions with participants at the Wetland Assessment Workshop at Stone Mountain, GA, in 1991.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. COL Bruce K. Howard, EN, was Commander.

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1 Introduction

The U.S. Army Corps of Engineers is charged under Section 404 of the Clean Water Act (33 USC 1344) with regulating the discharge of dredged or fill material in "waters of the United States," which includes wetlands and other special aquatic sites by definition. Under the Corps' 404 Regulatory Program, applications for a permit to discharge dredged or fill material are reviewed in accordance with the Corps Regulatory Program Regulations (33 CFR Parts 320-330), the U.S. Environmental Protection Agency (USEPA) 404(b)(1) Guidelines (40 CFR Part 230), and several Memoranda of Agreement between the Corps and USEPA. The review process considers the "public interest" by determining the effects of the proposed discharge on a variety of public interest factors, including wetlands, fish and wildlife, water quality, floodplains, economics, and mitigation. The effects of the proposed discharge on the public interest are considered in coming to a decision to issue or deny a permit through the "balancing" of the potentially favorable effects versus potentially detrimental effects of the proposed project.

This report focuses on the public interest review factor of wetlands, and on methods for determining the effects of discharging dredged or fill material in wetlands. Throughout this report, determining the effects of discharging dredged or fill material will be referred to as "assessing the functions of wetlands," in keeping with more common terminology. A variety of methods have been developed in recent years to assess the functions of wetlands; however, none has received widespread use within the 404 Regulatory Program. This is because the methods have in general failed to meet the administrative and technical requirements of the program. There continues, however, to be a strong interest in developing methods to assess the functions of wetlands in the context of the program. This report outlines a conceptual and organizational framework for developing such an assessment method. While the focus of attention is the 404 Regulatory Program, it is anticipated that the approach discussed in this report will result in an assessment method that will be useful in other regulatory, planning, and management activities involving wetland resources.

2 Existing Methods for Assessing the Functions of Wetlands

A number of methods have been developed in the past 10 to 15 years to assess the functions of wetlands. Some of these methods were designed specifically for use in wetland ecosystems, while others are adaptations of methods originally developed for upland or aquatic ecosystems. In the early to middle 1980s, several reviews of existing methods were completed. One review by Lonard et al. (1981) evaluated the applicability of methods in the context of the 404 Regulatory Program. The criteria used to judge each method included wetland functions addressed, geographic scope, data requirements, procedural flexibility, end products, and potential uses. The authors concluded that none of the methods examined were appropriate, in their present form, for use in the context of the 404 Regulatory Program, and made recommendations for improving the methods. A second review, by Nelson, Shea, and Logan (1982), considered methods designed to assess the impacts of dredging and fill activities on aquatic resources and wetlands. A variety of procedural formats were included in the review, including checklists, matrices, networks, mapping techniques, indices, habitat evaluation procedures, and ecosystem modeling. Finally, the USEPA (1984) summarized the reviews of Lonard et al. (1981) and Nelson, Shea, and Logan (1982), and considered additional methods for screening wetland functions and the potential adverse effects of individual projects on wetlands. The objective of this review was to provide a basis for adopting or modifying existing methods, or developing a new method for use in USEPA Region 5. The authors concluded that "a large number of methodologies for assessing various aspects of wetland values and functions have been developed. No single method reviewed, however, meets the requirements of a quick screening technique to determine a broad spectrum of wetland values and functions and the potential for adverse effects of construction grant-related activities."

Several methods have been developed, or revised, since these early reviews were published. The Wetland Evaluation Technique (Adamus et al. 1987), a revision of Adamus and Stockwell (1983), is a method designed to rapidly assess a broad range of functions in wetlands throughout the United States. Nationally, this method has received more attention and use than others, with the exception of the Habitat Evaluation Procedures (U.S. Fish and Wildlife Service 1980). However, use of this method is still quite limited when considering the large number of permits reviewed nationally each year. Other methods have received significant attention at the regional scale. The Hollands/Magee Method has been under continuous development and use in the northeastern and north-central United States for more than 10 years. An outline of this method and the models used to derive functional indices were published in a conference proceedings (Hollands and Magee 1986). Documentation of the original method is available (Normandeau Associates, Inc., and Interdisciplinary Environmental Planning, Inc. 1982), but a computerized, database version is proprietary.[1] Another method, known as the Connecticut Method (Amman, Franzen, and Johnson 1986), has been used in the New England area for several years. This method has recently been adapted for use in the state of New Hampshire (Amman and Stone 1991). Finally, the Wetland Evaluation Method (Wells 1988) was designed for use in the north-central United States. It is often characterized as a regional version of the Wetland Evaluation Technique; however, the models used to assess hydrologic and water quality functions set it apart from the national version. An extensive review of these methods, and other methods currently available, was recently published as part of the Statewide Wetland Management Techniques Report (World Wildlife Fund 1992).

Despite the variety of methods that have been developed for assessing the functions of wetlands, none has received widespread use within the context of the 404 Regulatory Program. As indicated, this is generally because the methods have failed to meet administrative and technical requirements of the program. Specific reasons why different methods have not received widespread use include:

- Extensive time and resource requirements for implementation.
- Subjectivity in implementation.
- Limited number of wetland functions considered.
- Applicability of method results.
- Concerns over technical validity.
- Limited geographic scope.

[1] Personal Communication, 1992, Mr. Garret G. Hollands, Fugro-McClelland East, Inc., Northboro, MA.

3 Regulatory, Administrative, and Technical Requirements

The regulatory requirement to determine the effects of discharging dredged or fill material on wetlands, or to assess the functions of wetlands, is set forth in the Corps Regulatory Program to Regulations (33 CFR Parts 320-330). Section 320(a) (1) of these regulations states, "The decision whether to issue a permit will be based on an evaluation of the probable impacts, including cumulative impacts, of the proposed activity and its intended use on the public interest." In the case of the 404 Regulatory Program, the "proposed activity" is the discharge of dredged or fill material. Section 320.4(b)(1) states, "Most wetlands constitute a productive and valuable resource, the unnecessary alteration or destruction of which should be discouraged as contrary to the public interest." Section 320.4(b)(2) identifies specific functions performed by wetlands that are important to the public interest. These functions are summarized in Table 1, along with their "values," that is, the benefits, goods, and services that result from them. Finally, Section 320.4(b)(4) states that "No permit will be granted which involves the alteration of wetlands identified as important in paragraph (b)(2) of this section unless the district engineer concludes that on the basis of the analysis required by paragraph (a) of this section, the benefits of the proposed alteration outweigh the damage to the wetlands resource." Paragraph (a), as cited above, discusses the process of balancing the benefits and detriments of a project on a suite of public interest review factors in coming to the decision to issue or deny a permit. In addition, it mandates compliance with the USEPA 404(b)(1) Guidelines, and outlines other general criteria to be considered in evaluating permit applications.

The implications that can be drawn from the regulations with respect to assessing the functions of wetlands are clear. These include:

- Wetlands are assumed to be a valuable resource.

- The importance of wetlands to the public interest can be expressed in terms of the specific functions that a wetland performs.

Table 1
Functions of Wetlands and Their Value

Functions of Wetlands	Value of the Functions of Wetlands
Store and/or convey floodwater	Reduce flood-related damage
Buffer storm surges	Reduce flood-related damage
Recharge groundwater	Maintain groundwater aquifers
Discharge groundwater	Maintain base flow for aquatic species
Stabilize shorelines	Minimize erosion damage
Stabilize streambanks	Minimize erosion damage
Detain/remove/transform nutrients	Maintain water quality
Detain/remove/transform contaminants	Maintain water quality
Detain/remove sediments	Maintain water quality
Maintain intra/inter ecosystem integrity	Maintain plant and animal populations Preserve endangered species Maintain biodiversity Provide renewable food and fiber products
Setting for cultural activities	Provide recreational opportunities Provide education/research opportunities Provide aesthetic enjoyment Preserve archeological and historical sites

- Public interest review requires that the effects of discharging dredged or fill material on wetlands be determined.
- This determination is made by assessing the effects of discharging dredged or fill material on the ability of wetlands to perform specific functions (i.e., assessing the functions of wetlands).
- The results of the determination must be explicitly considered in coming to the decision to issue or deny a permit.

Specific administrative requirements of the 404 Regulatory Program that are relevant to the development of a method to assess the functions of wetlands can also be identified. These include:

- The need for standardization to ensure that the method can be applied consistently in a diversity of wetland types throughout the United States.

- The need to use the best available technical information.

- The need to maintain compatibility with the time and resource framework of the 404 Regulatory Program.

The first requirement reflects the fact that the 404 Regulatory Program is a nationwide program, and the methods employed in the program must be capable of being applied consistently in the diversity of wetlands that exist in the United States. The second requirement reflects the fact that technical information concerning how wetlands perform specific functions is often limited. However, as research on wetland characteristics and processes continues, better information will become available. Consequently, methods for assessing the functions of wetlands must incorporate the best technical information currently available, while retaining the flexibility to integrate new information. The last requirement reflects the reality of the limited time and resources available for review of permit applications. The Corps processes over 50,000 general and individual permits annually, and time and resource constraints will continue to be a reality of the program in the foreseeable future.

In addition to the regulatory and administrative requirements, specific technical requirements are relevant in developing a method to assess the functions of wetlands in the context of the 404 Regulatory Program. These requirements are tied directly to determining the effects of discharging dredged or fill material, the requirement to avoid and minimize these effects, and the requirement to compensate for unavoidable effects. Specific technical questions that must be addressed can be identified at various steps in the permit review sequence. These include:

- What type of activity does the project propose, and is it dependent on waters of the United States?

- Do practicable alternatives exist for locating the project in an area that will reduce the impact of the project on waters of the United States?

- What functions does the wetland perform?

- How will the project impact the ability of the wetland to perform these functions?

- What steps can be taken to avoid or minimize these project impacts on wetland functions?

- What steps can be taken to compensate for unavoidable project impacts on wetland functions?

4 Wetland Classification

There is a tremendous diversity of wetlands in the United States (Cowardin et al. 1979, Mitsch and Gosselink 1986) that results from the wide range of climatic, hydrologic, and geomorphic conditions that are conducive to their development. Wetlands, for example, can occur as a result of cool or wet climatic conditions, seasonal overbank flooding, high water table, tidal inundation, impermeable soils, and various combinations of these and other factors. The great diversity of physical conditions under which wetlands occur is responsible for the great functional diversity exhibited by wetlands. This functional diversity creates a problem for the development of methods to assess the functions of wetlands because as functional diversity increases, so must the complexity of the assessment method. As a method increases in complexity, the time and resources required to implement the method increase accordingly. To develop a method for assessing the functions of wetlands that satisfies the regulatory, administrative, and technical requirements of the 404 Regulatory Program, it is first necessary to reduce the diversity of wetlands that any single assessment must address.

At least two approaches can be used to address this problem. Both represent compromises with positive and negative aspects. The first approach is to generalize a specific function of wetlands to the point that a single "model" (see below) can be used to assess that function in all wetlands. The positive side of this approach is that only one set of assessment models needs to be developed. The negative side is that generalized models have lower resolution, and lack the ability to identify real and significant changes in the ability of a wetland to perform specific functions that result from the discharge of dredged or fill material, or other impacts. This generalized approach is the one taken by many of the existing methods (Adamus et al. 1987; Amman, Frazen, and Johnson 1986). The experience of individual users (Dougherty 1989; Roberts, 1990[1]) and the lack of widespread use in the 404 Regulatory Program indicate that this approach has problems for a number of reasons, as indicated above.

The second approach is to group wetlands into classes that are functionally similar, and develop models to assess functions within each class. The

[1] Personal Communication, 1990, Dr. Thomas H. Roberts, Tennessee Technological University, Cookeville, TN.

negative side of this approach is that a greater number of assessment models must be developed, one set for each class of wetlands identified. The positive side of this approach is that it simplifies the process of developing and using assessment models. From the development point of view, by focusing attention on a class of wetlands that are functionally similar, it should be possible to develop assessment models that are simpler (since fewer model variables will need to be considered) and of higher resolution. From the user's point of view, the amount of data that must be collected and analyzed is reduced, making it possible to complete the assessment more quickly. As an example, tidal range is an important variable in models developed to assess the ability of coastal marshes to perform certain functions. However, tidal range is irrelevant in models developed to assess the ability of freshwater wetland depressions to perform those same functions. In the generalized approach, an assessment model must include all variables that are relevant in assessing the ability of any wetland to perform a certain function. In the classification approach, fewer model variables are necessary to assess the ability of wetlands in a certain class to perform a certain function. Another positive aspect of the classification approach is that it is more consistent with the actual situation one finds in the 404 Regulatory Program. In the majority of Corps Districts, the majority of permit activity focuses on one or, at most, a few wetland types in the region.

A variety of classifications have been developed for wetlands (Stewart and Kantrud 1971, Golet and Larsen 1974, Cowardin et al. 1979, Canadian Committee on Ecological Land Classification 1987). The most widely used system for classifying wetlands in the United States is the Cowardin et al. (1979) classification system developed for the U.S. Fish and Wildlife Service (Table 2, column 1). This classification was designed to meet four objectives: to describe ecological units that have certain homogenous natural attributes, to arrange these units in a system that will aid in decisions about resource management, to furnish units for inventory and mapping, and to provide uniformity in concepts and terminology throughout the United States. The National Wetland Inventory (NWI) maps wetland and deepwater habitats using the Cowardin classification because the inventory of wetlands at the national scale requires large amounts of spatial data. The Cowardin classification is well-suited for this application because it is based on characteristics that can be identified from a remote sensing data platform. However, the use of structural vegetative characteristics as the primary criterion for classifying wetlands may be inappropriate because it often places wetlands that are functionally very different into the same class (Semeniuk 1987).

Another classification approach that has been frequently mentioned in the context of assessing the functions of wetlands is geographic "regionalization" (Sather and Stuber 1984). Regionalization is a classification of wetlands based on the large-scale, interregional factors that influence how a wetland functions. For example, interregional climatic changes can affect how wetlands function because of differences in precipitation to evapotranspiration ratio, or type of precipitation and its effect on stream hydrographs (i.e., snowmelt versus rain-driven). A variety of regional factors clearly affect the functional capability of

Table 2
Comparison of Cowardin, EMAP, and Hydrogeomorphic Classification

Cowardin - System/Subsystem/ Class (Cowardin et al. 1979)	Environmental Monitoring Assessment Program for Wetlands - System/Class (Liebowitz, Squires, and Baker 1991)	Hydrogeomorphic Class/Subclass (Brinson 1992)
Marine Subtidal Intertidal	Marine Aquatic bed (EMAP-NC)	(Marine) Fringe
Estuarine Subtidal Intertidal	Estuarine Aquatic bed (EMAP-NC) Emergent Scrub-shrub Forested Unconsolidated shore (EMAP-NC)	(Estuarine) Fringe Channel
Riverine Tidal Lower perennial Upper perennial Intermittent		(Riverine) Channel Tidal Lower perennial Upper perennial Intermittent
Lacustrine Aquatic bed Unconsolidated shore		(Lacustrine) Depression *Groundwater* Surface water
Palustrine Persistent emergent Scrub-shrub Forest	Palustrine	(Palustrine) Slope Groundwater Surface water
Persistent emergent Scrub-shrub Forest	(Riparian - R locator) Emergent Scrub-shrub Forest	Floodplain Tidal Lower perennial Upper perennial Intermittent
Persistent emergent Scrub-shrub Forest	(Lacustrine - L locator) Emergent Scrub-shrub Forest	Fringe Lake
Aquatic bed Persistent emergent Scrub-shrub Forest	(Basin - no locator) Shallows Emergent Scrub-shrub Forest	Depression Groundwater *Surface water*
Moss-lichen	Moss-lichen	Expansive Peatland

a wetland. However, many factors operating at the intraregional scale are just as important, if not more important, in terms of controlling how a wetland functions. In some geographic regions of the country, the intraregional diversity of wetlands approaches the diversity of wetlands in the entire country. For this reason, a classification of wetlands based on factors operating only at the regional scale is inadequate. Regionalization must be linked with a mechanism for classifying wetlands into functionally similar groups based on factors operating at the interregional scale.

Recently, Brinson (1992) proposed a classification of wetlands based on the hydrogeomorphic characteristics of geomorphic setting, water source, and hydrodynamics. The classification is based on characteristics that are important in controlling how wetlands function (Gosselink and Turner 1978, Mitsch and Gosselink 1986) and is appropriate for identifying wetland classes that are functionally similar. A preliminary list of hydrogeomorphic wetland classes and subclasses was developed during the Wetland Assessment Workshop in March 1991. These are shown in the left column of Table 3. Geomorphic setting defines six wetland classes at the highest level of the classification hierarchy: Depressional, Riverine, Fringe, Slope, Channel, and Expansive peatland. The subclasses listed below each class are based on water source and hydrodynamic characteristics of the wetland. For example, under the depressional class, the functionally distinct subclasses Closed, Semiclosed, and Open are tentatively identified.

The proposed hydrogeomorphic classification does not explicitly include all factors that control how wetlands function. For example, regional variables such as climate or vegetation are not classification factors, but could eventually be included at lower levels of the classification hierarchy, or as variables in models for assessing specific functions. Similarly, the classification does not address short- and long-term temporal factors such as beaver activity and river meandering, which may be important in assessing certain functions (Klimas and Smith, in preparation).

It should be clear that the hydrogeomorphic classification is not a method for assessing the functions of wetlands. Rather, the classification functions as a preliminary step in an overall method, or procedure, for assessing the functions of wetlands. The classification simplifies application of the procedure by focusing attention on a specific class of wetlands, rather than all wetlands as discussed previously. Use of a hydrogeomorphic classification does not preclude grouping wetlands based on other characteristics, considerations, or objectives, and developing models for assessing these wetland classes. For example, in certain geographic areas it may be appropriate to develop assessment models for a specific type of wetland receiving extensive development pressure or other types of widspread or intensive impact. The Environmental Monitoring Assessment Program for Wetlands (EMAP-Wetlands) is using a modified version of the Cowardin system to classify wetlands in its program to monitor long-term health of wetlands (Liebowitz, Squires, and Baker 1991).

Table 3
Wetland Hydrogeomorphic Type and Subtype and Functions Matrix

Hydrogeomorphic Classes/Subclasses	Hydrologic Functions	Biogeochemical Functions	Biological/ Ecological Functions	Cultural Functions
Depressional				
Closed				
Semiclosed				
Open				
Riverine				
Tidal				
Lower perennial				
Upper perennial				
Intermittent/ephemeral				
Fringe				
Coastal				
Lake				
Slope				
Channel				
Expansive peatland				

Different wetland classifications are necessary to satisfy different objectives, and there are many reasons to ensure that an exchange of information is possible. For example, the wetland maps and the status and trends reports produced by NWI (Dahl and Johnson 1991) represent one of the most accessible sources of wetland information. Much of the information contained in these maps and reports, such as vegetation structure, hydrologic regime, water quality, and substrate type, is relevant in assessing the functions of wetlands. Efforts are currently under way to determine ways to maximize use of the information on NWI maps in assessing the functions of wetlands.[1] Table 2 shows cross-referencing between the Cowardin classification, the EMAP-Wetlands modification to Cowardin, and the hydrogeomorphic classification proposed by Brinson (1992).

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[1] Personal Communication, 1992, Dr. William O. Wilen, U.S. Fish and Wildlife Service, Washington, DC.

5 Models for Assessing the Functions of Wetlands

Assessing the ability of a wetland to perform specific functions requires an understanding of which specific characteristics of the wetland and its surroundings are important in the performance of a function, and how they interrelate. In the assessment method, this understanding must be formalized into an "assessment model," which is a simplified representation of reality that presents the significant features or relationships of the function in a generalized form. A good model is a selective approximation that excludes incidental details, observations, and measurements to concentrate on the fundamental aspects of reality of the phenomenon being modeled (Gélinas 1988). In the context of the 404 Program, an assessment model serves as the means for assessing (i.e., measuring, estimating, or predicting) the ability of a wetland to perform a specific function before and after the discharge of dredged or fill material. A number of models have been developed to describe, measure, and predict the ability of wetlands to perform functions. They have taken a variety of forms, including indices (Amman, Frazen, and Johnson 1986; Hollands and Magee 1986; and Amman and Stone 1991), interpretation keys (Adamus 1983, Adamus et al. 1987), rule-based models (Starfield 1990), mechanistic models (U.S. Fish and Wildlife Service 1980), graphical or spatial models (Poiani and Johnson 1991), numerical models (Costanza and Sklar 1985), and simulation models (Mitsch, Straskraba, and Jorgensen 1988).

The single most important factor that distinguishes one model from another is the degree of probability with which the model represents or predicts reality (Chorley and Haggett 1967). Depending on the nature of the technical information available for developing a model, the skill of the modeler, and the nature of the data used as input to the model, a model will provide a more or less accurate measure of the ability of a wetland to perform a function. For the most part, the information concerning how wetlands function is inadequate for developing quantitative assessment models. Hydrologic functions of wetlands associated with surface water may be an exception because of past efforts to model surface water resources (Hydrologic Engineering Center 1990). Hollands (1986) argued this point with respect to relationship between wetlands and groundwater when he described the difficulties associated with the collection and analysis of data, and the identification of accurate indicators (summarized below).

> There are no shortcuts to accurately predict the groundwater function of a wetland. Detailed hydrogeologic data is necessary. The data is expensive and may require a year or more of groundwater elevation observations before recharge/discharge relationships can be understood. The state of the art of understanding wetland water budgets is in its beginning stages and much more research is needed before accurate predictors are developed for non-hydrogeologists. Since hydrology is the driving force of wetland functions, and reliable wetland hydrology predictors do not exist, it is doubtful if accurate assessments can be made of many other wetland functions. There are few shortcuts to understanding wetland hydrologic functions. Detailed, wetland-specific, multi-disciplinary investigations conducted by qualified scientists are needed.

The extent of our knowledge and information is just one side of the coin. The other side, as pointed out by Hollands, is the ability of users to supply the data necessary to run a model. For certain surface water hydrologic functions, numerical mathematical models are available for predicting the ability of a wetland to perform (Hydrologic Engineering Center 1990). The problem in these situations is that given the time and resources available, it is difficult to acquire and analyze the data necessary to run these numerical models. Unfortunately, the lack of technical information, or the difficulty in acquiring or analyzing it, does not alter the task of regulators, planners, and managers who must make decisions concerning wetland resources on the basis of available information. The challenge, therefore, is still to develop models for assessing the functions of wetlands given the level of information available in a manner commensurate with the time and resources available in the 404 permit review process. The most realistic approach for accomplishing this, given the constraints of the 404 Regulatory Program and the general lack of quantitative information, is to develop qualtitative models of wetland function. A commitment to the development of qualitative models of wetland function does not mean that when adequate technical information is available, more accurate quantitative models, with increased data input requirements, should not be developed. If both qualitative and quantitative models of wetland function are available, users should have the option to select the assessment model that balances their requirements for accuracy with available time and resources.

The fact that most of the information and knowledge concerning how wetlands function is of a qualitative nature is hardly unique to wetlands. Rather, this is true of most ecological knowledge (Rykiel 1989). Recently, progress has been made with modeling approaches that make use of qualitative ecological information. Rykiel (1989) summarized the potential role and usefulness of such approaches as follows:

> Much ecological knowledge is qualitative and fuzzy, expressed verbally and diagrammatically. Ecologists have no effective technology for using this vast knowledge in a meaningful way. The core of ecology does not yet exist in the form of an accepted set of mathematical expressions. There is no evident point to waiting around for ecology to become primarily quantitative, and in the mean time ignoring the predictive power of qualitative knowledge. In reality,

ecologists have considerable knowledge in their heads and not many ways to make this knowledge explicit, well-organized, and computer processable. Artificial intelligence research may provide tools in the form of symbolic computing techniques for manipulating qualitative knowledge. Many questions of interest in ecology (and especially to decisionmakers) can be answered in terms of "better or worse, more or less, sooner or later," etc.

The search for quantitative knowledge must continue to discover ecological relationships that can be expressed and manipulated with the power of mathematics. The challenge is to integrate quantitative knowledge with qualitative knowledge to deal with the complexity of ecological and environmental systems. Scientifically valid qualitative predictions can be made even when quantitative predictions cannot. Often quantitative methods are used to arrive at a qualitative prediction or decision. When quantitative methods are inadequate or lacking, estimates, predictions, and decisions must still be made in both scientific and management situations.

The best documented of these qualitative modeling approaches is known as qualitative, rule-based modeling (Widman, Loparo, and Nielsen 1989). Starfield and Bleloch (1986) first showed how qualitative rules could be used to modify conventional quantitative models to build dynamic, qualitative models. Other good examples of this modeling approach can be found in Starfield, Farm, and Taylor (1989) and Starfield (1990). The rule-based approach should be considered, along with more traditional approaches for developing models to assess the functions of wetlands, because it makes use of the qualitative information that is often the only type of information available. In addition, the type of input data required to run these models is compatible with the limited time and resources inherent in the program.

6 Assessing the Value of the Functions of Wetlands

Assessing the functions of wetlands provides a means for comparing the ability of two wetlands, separated in space or time, to perform specific functions. However, it does not provide a means for comparing the value of the functions performed by a wetland with the value of other public interest factors considered during the public interest review. Value has been characterized by Brown (1984) as "held" and "assigned." Held values are the precepts or ideals that individuals, or groups, believe in. Assigned values represent the relative importance of things to individuals, or groups. Balancing the asssigned value of different public interest review factors is a more subjective process because assigned value is specific to individuals, or groups, and their situation (Siden and Worrell 1979).

Society commonly designates assigned value to benefits, goods, and services in economic terms. The economic value, or market price, represents the integration of all the factors that determine the willingness of people to pay for the benefits, goods, and services on the open market. The economic value of some of the benefits, goods, and services results from functions performed by wetlands (Table 1) can be determined. For example, forested wetlands are often managed to provide timber or other wood products for which market prices have been established through exchange on the open market. The value of forest products from wetlands can be compared directly to the value of other public interest review factors in making a permit decision.

However, unlike timber or wood products, many of the benefits, goods, or services resulting from the functions performed by wetlands are not exchanged on the open market, and consequently have no established economic value indicated by market price. These benefits, goods, and services accrue to society "in common." Society recognizes the value of commonly held benefits, goods, and services through the passage of laws and by promulgating regulations designed to protect benefits, goods, and services. For example, in the United States, laws exist to protect and maintain clean water, clean air, natural lands, cultural and historic sites, and endangered species.

A variety of methods are available to establish the economic value of benefits, goods, and services for which no market, or market price, exists. These include replacement cost methods, travel cost methods, contingent valuation methods, cojoint analysis, and others (Shabman and Batie 1988, Mitchell and Carson 1989, Luzar and Gan 1991). In addition, there are a variety of methods for determining value based on noneconomic standards (Siden and Worrell 1979). As indicated, the objective of this report is to outline a conceptual and organizational framework for developing a method to assess the ability of wetlands to perform specific functions, not to determine the value of these functions and their associated benefits, goods, and services. However, recommendations and guidelines for assessing the value of the functions performed by wetlands are currently being developed in another Research Area of the Wetlands Research Program at the Waterways Experiment Station (Henderson, in preparation).

7 Organizational Structure and Approach for Development

The organizational structure and approach for developing a procedure to assess the ability of a wetland to perform functions is shown in Figure 1. The interdisciplinary working groups, listed at the bottom of the figure, are responsible for developing models of wetland function for hydrologic, biogeochemical, and biological/ecological functions for specific hydrogeomorphic wetland classes. Wetland Class Working Groups have been established for priority wetland types, including riverine, depressional, and fringe/coastal hydrogeomorphic (Table 3). Each of the Wetland Class Working Group chairmen coordinates the activities of his group with other Wetland Class Working Groups. The Assessment Procedures Working Group is responsible for developing the overall assessment procedure, and the Corps Field Oversight Committee determines the appropriateness of the assessment procedure and models of wetland function as they are developed. Coordination among all organizational elements is facilitated by staff from the Wetlands Branch of the

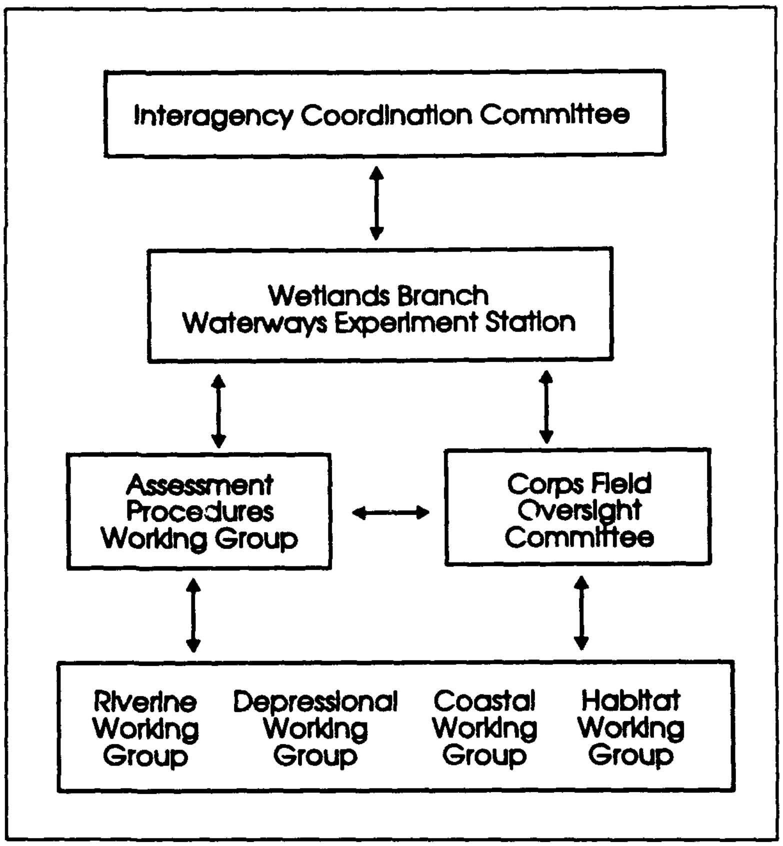

Figure 1. Organizational structure for developing a method to assess wetland functions

WES Environmental Laboratory. Coordination with other agencies will take place through the extant interagency Wetland Coordination Committee, which consists of representatives from the U.S. Army Corps of Engineers, Federal Highway Administration, USEPA, U.S. Fish and Wildlife Service, and Soil Conservation Service.

8 Assessment Procedures Working Group

An Assessment Procedures Working Group was formed during the first quarter of FY 92. The task of this group is to develop the overall assessment procedure and to establish guidelines for its use. This will include identifying and defining of wetland functions; identifying methods to define the wetland areas being assessed; identifying ways to use the procedure in impact analysis, avoidance, minimization, and mitigation; and setting guidelines for developing models of wetland function. This working group consists of individuals with experience in the development of assessment procedures, interagency representatives, and representatives from WES.

9 Wetland Class Working Groups

Three interdisciplinary working groups were formed in the first quarter of FY 92 to address the riverine, depressional, and fringe (coastal) wetland classes. Each group consists of six to eight members, with a designated chairperson who coordinates activities of the group and acts as a liaison with WES. Additional working groups may be formed for the other hydrogeomorphic wetland classes as priorities and resources dictate.

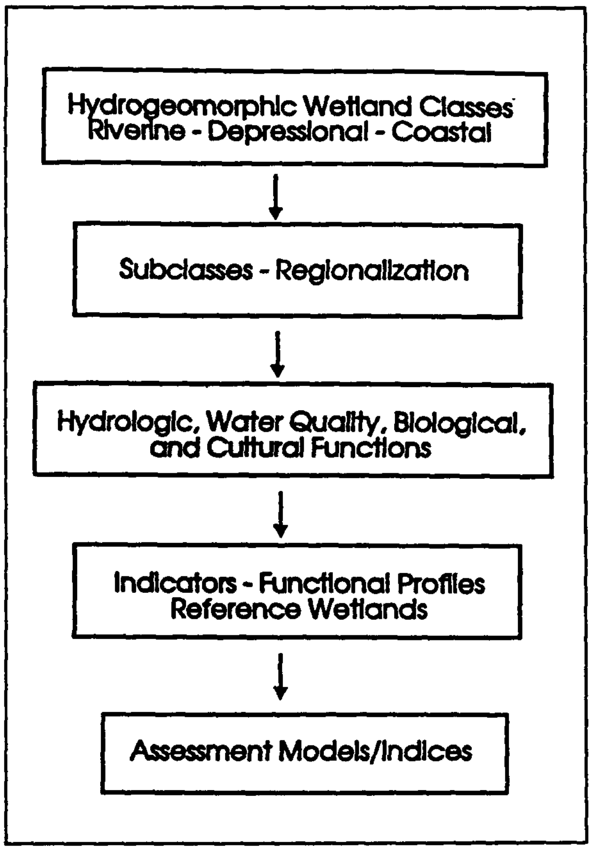

Figure 2. Wetland class working groups procedural steps

The objective of the working groups is to identify indicators and to develop models of wetland function for assessing the hydrologic and biogeochemical functions for a specific hydrogeomorphic wetland class and its subclasses (Figure 2). Each group is responsible for completing certain tasks and developing specific products. These tasks and products are to be completed in three phases, as outlined below. Phases 1-3 roughly correspond to FYs 92-94.

Phase 1 Tasks and Products:

- Characterize hydrogeomorphic wetland class.
- Characterize distinct subclasses within each hydrogeomorphic class.
- Initiate compilation, review, and synthesis of pertinent literature.
- Identify site-specific and landscape-scale hydrologic and biogeochemical functions of wetlands in the hydrogeomorphic wetland type.

- Identify indicators for each wetland function.
- Develop conceptual model for each function showing indicators, processes, and their relationships.
- Draft functional profile for hydrogeomorphic wetland type.

Phase 2 Tasks and Products:

- Make recommendations concerning format of models for assessing wetland functions (i.e., word models, indices, qualitative rule-based models, numeric models).
- Make recommendations concerning implementation of models (i.e., bounding criteria, definition of terminology).
- Make recommendations concerning use of model results (i.e., HEP-like functional units).
- Develop draft models for assessing wetland functions.
- Propose wetland sites representative of hydrogeomorphic wetland type and subtype for calibration and field testing of models.
- Draft models for assessing wetland functions.

Phase 3 Tasks and Products:

- Calibrate and field-test models.
- Revise models for assessing wetland functions.
- Final functional profile for hydrogeomorphic wetland type.
- Compile appendix describing calibration and field testing, and the results.
- Prepare final models for assessing wetland functions.
- Identify reference wetlands for hydrogeomorphic wetland type.
- Identify research needs for improving assessment capability.

10 Habitat Working Group

A Habitat Functions Working Group was formed in the latter part of FY 91. The purpose of this working group is to streamline existing models, or develop new models, for assessing habitat functions of wetlands. This working group focuses on the habitat functions of selected wetland types, such as prairie potholes, red maple swamps, and bottomland hardwoods. This working group consists of representatives from the U.S. Fish and Wildlife Service National Ecology Research Center, other individuals active in the development of models for assessing the habitat function of wetlands, and a representative from WES.

11 Corps Oversight Committee

A Corps Oversight Committee will be formed during the third quarter of FY 93. The task of this committee will be to oversee development of the assessment procedure and models of wetland function to ensure that they are appropriate in the context of the 404 Regulatory Program and otherwise meet the needs of Corps field elements. This committee will also be responsible for establishing a network of individuals in Districts willing to serve as points of contact for the flow of information concerning the assessment of wetland functions. The committee will consist of representatives from the regulatory and planning branches of the Corps Districts or field offices and one representative from WES.

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13. ABSTRACT *(Maximum 200 words)*

Wetland ecosystems perform many functions that are beneficial to society. Assessing the ability of wetlands to perform these functions is an important part of the regulatory, planning, and management activities of the U.S. Army Corps of Engineers and other Federal agencies. Various methods have been developed for assessing the functions of wetlands; however, none has received widespread acceptance or use within the Corps because of a basic failure to meet both the technical and programmatic requirements of the 404 Regulatory Program. As a result, the assessment of wetland functions is often completed using subjective and, in some cases, undocumented methods.

This report outlines a conceptual and organizational framework for developing a procedure to assess the functions of wetlands in the context of the 404 Regulatory Program. The procedure begins with the classification of wetlands into "functional classes" based on hydrogeomorphic characteristics. For each wetland class, a suite of appropriate functions are identified along with functional indicators. Functional indicators are used to characterize the physical, chemical, and biological properties and processes of the wetland and the surrounding area, and to predict the functional capability of the wetland in the context of a reference wetland population.

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